MODIS SCIENCE DATA SUPPORT TEAM PRESENTATION

July 19, 1991

AGENDA

1. Action Items
2. MODIS Airborne Simulator
3. MODIS Image Rectification Interviews
4. MODIS Assumptions/Tracking List

ACTION ITEMS

05/03/91 [Lloyd Carpenter and Tom Goff]: Prepare a Level-1 processing assumptions, questions and issues list, to be distributed to the Science Team Members and the MCST for comment. (The list, the executive summary, information on the EOS Platform Ancillary Data, and a cover letter were delivered for signature and distribution.) STATUS: Open. Due date 06/07/91.

05/31/91 [Liam Gumley]: Establish a connection with the proper person at Ames Research Center for communication on MAS formats, an interface control document, agreements, etc. STATUS: Open. Due date 07/19/91

06/07/91 [Liam Gumley]: Speak to Alan Strahler, when he returns, regarding his MAS requirements. (This item is delayed until Liam returns from Wisconsin.) STATUS: Open. Due date 07/05/91

06/21/91 [Liam Gumley]: Obtain a copy of all available MAS Level-1B processing software and any existing documentation from the University of Wisconsin at Madison for porting to a system at GSFC. (Liam is at Wisconsin for this purpose.) STATUS: Open. Due date 07/19/91

06/21/91 [Liam Gumley]: Generate a complete milestone schedule for conversion, installation and testing of all modules of the MAS Level-1B processing software at GSFC. Draw up an agreement between the SDST and Mike King of what will be done. STATUS: Open. Due date 07/19/91

05/31/91 [Al McKay and Phil Ardanuy]: Examine the effects of MODIS data product granule size on Level-1 processing, reprocessing, archival, distribution, etc. (Work is continuing.) STATUS: Open. Due Date 06/21/91

06/28/91 [Lloyd Carpenter and Tom Goff]: Prepare a detailed list of scheduler assumptions in relation to Level-1 MODIS processing scenarios. STATUS: Open. Due date 07/26/91.

06/28/91 [Lloyd Carpenter]: Prepare a letter to Bill Barnes inquiring as to whether or not the platform ancillary data will be included with the MODIS instrument data. (The letter was signed.) STATUS: Closed. Due date 07/05/91.

06/28/91 [Tom Goff]: Prepare an estimate of the total cost of Cadre's Teamwork CASE tools and the Soft Bench umbrella product for the MODIS environment. (A report was given at the meeting.) STATUS: Closed. Due date 07/05/91.

ACTION ITEMS FROM SDST MEETING 07/05/91 [Liam Gumley]

A visit to Madison Wisconsin was made from 05/10/91 to 05/12/91. Most of the following action items address the results of this visit.

(1) Establish a connection with the proper person at Ames Research Center.

According to Chris Moeller at Wisconsin, the person to contact at Ames Research Center is

Mr. Jeff Myers
High Altitude Missions Branch
NASA Ames Research Center
Mail Stop 240-12
Moffett Field CA 94035
(415) 694-6252

Informal contact has been made with Jeff Myers to inform him that the SDST will be requesting MAS data from November onwards. A request will also be made to obtain information about data tape formats (as verification to the information obtained from Wisconsin). A more formal contact can be arranged as necessary.

(2) Speak to Alan Strahler regarding his requirements for MAS Level-1B processing.

Apparently my visit to Wisconsin coincided with Alan Strahler's return to Boston. However he has since left for China and will not return until August. Given that the MAS processing development will be well underway by that time, this action item should perhaps be removed from the list, and pursued as Strahler's schedule permits. We have already received input from Chris Justice on the requirements of the land disciplines for MAS.

(3) Obtain a copy of all relevant MAMS Level-1B processing software and documentation from Wisconsin.

This was accomplished during my visit to Madison Wisconsin last week. I was able to obtain source code, source code descriptions, MAMS test data, and INS test data. Chris Moeller also gave me very helpful advice on the strategies he uses for calibrating and geolocating MAMS data. In summary, the materials obtained were

(1) 6250 bpi magnetic tape containing MAMS Level-1A data from a flight over the Mississippi Delta on 04/15/90
(2) 6250 bpi magnetic tape containing ER-2 INS data from the same flight
(3) Information on the MAMS and INS tape formats
(4) 6275 lines of MCIDAS FORTRAN source code for calibrating and navigating MAMS data

(5) Descriptions of the source code
(6) Imagery of a portion of the MAMS data from 04/15/90 where selected pixels are marked with their calibrated radiances and earth locations.
(7) Plots of the INS test data versus time
(8) Summary of the MAMS Level-1A to Level-1B processing
(9) Summary of a discussion between Chris Moeller and Jeff Myers (Ames) regarding details of the MAMS and INS data.

Both Chris Moeller and Paul Menzel at Wisconsin were very helpful in offering their code and advice on the MAS processing. Chris Moeller is an especially valuable contact for information about operational aspects of MAMS data processing. Paul Menzel informed me that it is currently planned for the FIRE experiment to start on 11/18/91 and run for about 3 weeks.

(4) Generate a complete milestone schedule for conversion, installation and testing of the MAS Level-1B processing software at GSFC. Draw up an agreement between the SDST and Mike King of what will be done.

A schedule has been drafted based on the one shown in the SDST presentation of 06/21/91. Progress so far matches that shown in the 06/21/91 schedule.

The agreement between Mike King and the SDST will depend on the specification of two aspects of the MAS processing. These are

(1) Calibration.
Wisconsin calibrates the infrared bands in an individual scanline using the blackbody data from that scanline only - no averaging of blackbody data is done. Averaging over up to 16 lines has been investigated, but no significant benefit was identified.

(2) Geolocation.
Geolocation is done on a straight line flight track basis. Linear regression relationships are developed for nadir latitude/longitude, heading, altitude etc. for each straight line flight track. Pixels in that flight track are then geolocated using aircraft positions derived from the regression relationship. It should be noted that it is possible to geolocate every scan line using the INS data that exists for that scan line, even though the INS and MAMS data are not updated at the same rate.

It is planned to use the current Wisconsin strategies for calibration and geolocation in the first version of the MAS Level-1B processing code. As the project continues, refinements may be made to these strategies.

Schedule for development of a MAS Level-1B processing system
18 July 1991

June 1991

- Survey user requirements for MAS Level-1B data.
Status: Completed.
Alan Strahler will be contacted as his schedule permits.

- Investigate hardware options available for processing.
Status: Completed.

July 1991

- Obtain calibration and geolocation software, and MAMS test data from Wisconsin.
Status: Completed.
This was accomplished during a trip to Wisconsin from 07/09/91 to 07/12/91.

- Start source code conversion/development on selected processing platform.
Status: Underway.
The LTP VAX system has been selected as the initial processing platform. An account is now operational on this system. The MAMS source code has been transferred to the VAX.

- Investigate imaging software available.
Status: Underway.
The imaging platform will be the LTP Silicon Graphics IRIS running PCI imaging software. Review of PCI features and documentation is underway. During development, the IMDISP program on an IBM-PC will also be used.

- Investigate format for MAS Level-1B output data.
Status: Underway.
The basic output data format will be as outlined in the SDST presentation of 07/05/91 (conversion of this data to Hierarchical Data Format (HDF) will be undertaken as a separate task, with a separate schedule). The basic philosophy is to provide the user with calibrated, geolocated radiances, and also include all the data that was provided in the Level-1A dataset (e.g. INS data, engineering data). Advice from Chris Moeller and the Science Team will also guide which specific items are included in the output data set.

August 1991

- Continue calibration and geolocation source code conversion, development and documentation.

- Investigate strategies for viewing image data using PCI.

- Produce initial imagery of MAMS test data.

- Finalize design of MAS Level-1B output data format.

September 1991

- Continue calibration and geolocation source code conversion, development and documentation.

- Start testing calibration and geolocation results against MAMS MCIDAS produced data.

- Finalize image viewing system using PCI for MAMS Level-1B users.

October 1991

- Complete calibration and geolocation code conversion and development, Version 1.0.

- Test code with complete processing run using MAMS test data from Wisconsin - possibly using different test data set than the one used in development.

- Complete code documentation and user guides.

- Document image viewing system for MAS Level-1B users. Introduce users at GSFC to image viewing system.

- Confirm MAS November delivery schedule with Ames contact (Jeff Myers).

November 1991

- Obtain MAS Level-1A data as soon as possible from Ames.

- Test the processing system with MAS Level-1A data and correct any bugs.

- Process the first set of MAS Level-1A data and distribute to users in the selected data format.

- Assist GSFC users with the image viewing system.

Image Rectification: An Interview with Dr. Ramapriyan

Based on Thematic Mapper (TM) experience, Dr. Ramapriyan (Rama) doubts that the 0.2 pixel (50m) image registration accuracy desired within the MODIS land disciplines can be routinely achieved. Under exceptionally good conditions, scene-to-scene registration within 0.2 pixels may be achievable. The most critical issue is platform attitude stability and rapid changes in the attitude rate that may be associated with the motion of MODIS or other instruments on the platform. If the attitude rate varies slowly, the desired accuracy may be achievable in regions where good ground control points are available. TM achieved a registration accuracy of about 0.5 pixel with respect to absolute Earth coordinates and about 0.2 pixel accuracy scene-to-scene. The relative positions of TM pixels within a single image were accurate to less than 0.2 pixel and band-to-band registration was accurate to 0.1 pixel.

TM had an Angular Displacement Sensor (ADS) that provided relatively good attitude information (thirty readings per scan) and the greatest uncertainty for TM was associated with platform position. Ground control information is relatively useful for resolving position uncertainties and relatively difficult to use to resolve attitude uncertainties (several ground control points are required to resolve attitude ambiguities). Three non-linear ground control points are minimum for determining an affine transformation (correction for translation, rotation, and image skew [for TM]). Correction may be done for each individual scan or for a whole scene. Typically, six control points distributed over all regions of a scene are required to correct the scene. Ground control points specifically suited to the MODIS resolution (250m) and spectral bands (red and near-IR) are needed.

Most of the additional processing required to use ground control points for image registration is associated with the location of ground control points in the newly acquired image. One of the potentially applicable techniques uses stepwise convolution evaluated as the reference image (ground control "chip") is stepped over a search region. For TM, a special purpose processor was used to speed up these relatively repetitious calculations. To estimate requirements, a chip region of 64 x 64 pixels might be stepped over a 128 x 128 pixel search window. A Cray computer may be capable of doing the calculations, but project needs are probably better served with a special purpose processor dedicated to this function. Other major impacts from ground-based image rectification are not foreseen.

Image Rectification:
A Telephone Interview with Dr. Ken Jones at JPL.

Dr. Jones is doing preliminary studies on MISR image rectification using ground control. Since the MODIS and MISR instruments are on the same platform and since MISR has a high-resolution channel with 240m resolution, results may carry over directly for MODIS 250m channels.

Dr. Jones believes that the 50m registration accuracy requirement of the MODIS land discipline team can be met if the high-frequency component in platform attitude knowledge (jitter) can be made substantially smaller than a pixel. GE has agreed to a jitter envelope (3 sigma) that increases linearly from 0 to 7 arcseconds in a six second time period and is then limited to 7 arcseconds for up to 1000 seconds.

MISR will probably register on a scan basis using several GCPs in each scan. Before launch, Dr. Jan-Peter Muller will develop an initial set of MISR control images taken from results for other instruments. At launch, MISR images to match each control image will be acquired, and once the registration of the MISR image is established, the MISR image will itself become the new reference image, and future MISR image matching will be done against these MISR images used as a ground control baseline. The repeat period for the images is the same as the 16 day repeat period for the EOS-A orbit. One advantage of using the MISR image as a reference is that absolute geodetic coordinates are not required, and the position of whole continents (say) can be readily adjusted as more precise information on relative continental locations becomes available. It may take several years to acquire a complete set of reference images for the whole Earth.

Suitable control regions should be flat or should have a well defined elevation. Dr. Jones thinks that, of the two MODIS high-resolution bands, the near-IR band will be most useful for ground control since atmospheric effects are less in the infrared.

Human intervention may be required to verify the initial selection of MISR control images from the prelaunch list of GCPs. Once MISR control images are available, observed locations of the control images are used to solve for unknown coefficients in a precise mathematical model that gives the location of all pixels. The search for control images in the received image can be compute intensive; a special purpose processor may be used, or a transputer may be available in the EOS time frame.

If MODIS image quality is affected by inadequate MTF performance or degraded by other transient effects related the the sensors, Dr. Jones believes that MODIS registration accuracy may be degraded to perhaps 100m. He believes that the differences in images accurate to 50m and those accurate to 100m will be slight.

TONS and EOS Platform Position: A Telephone Conversation with Dave Folta

Since the TDRSS On-board Navigation System (TONS) is a likely successor to the Global Positioning System (GPS), information on the capabilities of TONS is needed to support MODIS image rectification discussions.

It appears that TONS provides platform position and velocity knowledge but will not provide improved platform attitude knowledge. Attitude information will be derived from the on-board platform navigation system as with GPS. The announced position accuracy of TONS is 60m (3 sigma, each axis). The system also supports time determination accurate to 10 microseconds.

Image Rectification:
A Telephone Conversation with Dan Steinwand
at the EROS Data Center

The EROS Data Center has provided software, ground control point information, and image rectification processing for various Landsat and AVHRR programs.

The most essential element of a good image rectification technique is a mathematical model that relates pixels observed by the instrument to corresponding locations on the surface of the Earth. All subtleties and higher order perturbations that can be evaluated should be included in the model.

This model is then used with ancillary ground information and early images from the instrument to establish a base image (as seen by the instrument) for the region of interest. Selected regions (usually 64 x 64 pixel chips) from the base image will be matched with corresponding regions in the observed image and will serve as control points for the application of image rectification techniques. A base image is established once and used for all subsequent image comparisons. Since all subsequent images are referenced to the same control image, individual differences among the subsequent images are minimized and nearly optimal coregistration is obtained among all successive images of a region. Hand matching techniques and special purpose computer runs may be required to establish the base image.

Using the mathematical model and the current best knowledge of platform position and attitude, an observed image can be converted to a corresponding image that presents the data as it would appear on a suitable map projection of the Earth. For large areas, EDC has settled on the Lambert Azimuthal Equal Area projection. Appropriate control regions selected from the base image are converted to the same projection and it is in this projection of the observed and reference data that a match is attempted. At EDC, images may be translated (given an x and y offset across the whole image) and rotated to obtain a best (least squares) fit between the observed and reference images. The translation and rotation that corresponds to the best fit is then converted back to a corresponding position and attitude correction at the platform (and desired platform corrections have been derived). Information generated for the Lambert Azimuthal Equal Area projection is discarded.

The corrected platform position and attitude are then applied directly to the original observation data to obtain a best estimate of pixel positions for the observed image.

Control regions near instrument nadir are usually used to avoid the geometric distortion and atmospheric effects often associated with high nadir angles. Dan thinks that the 250m resolution of the instrument will make some man-made features visible; more features may be available for use as control points at this resolution than would be available with coarser resolution instruments. Dan thinks that the wavelength of the observation will be important in control point selection and that seasonal effects may be important. Sometimes four distinct sets of ground control points have been used: one set for each season of the year.

MODIS TRACKING LIST

Assumptions, Questions, and Tracking

compiled by the

MODIS Science Data Support Team

18 July 1991 - DRAFT VERSION

This master list of assumptions, tracking items and questions approaches a comprehensive list of all items associated with the design of the MODIS data processing. The intent is to clarify issues and prevent misunderstandings. Items that are assumptions have been included in the current MODIS processing design. They may be modified in future revisions as the design becomes further refined. Tracking items are included as reminders for other phases of the design. Questions for groups other than the MODIS Science Data Support Team are included with time tagged responses as received. This list is a living document that will change as needed.

Each item includes justification and trade-off information. Items that require a response from other groups will include dates for tracking purposes. The internal tracking number is included in parentheses in the title of each list item.

See the glossary at the end of this document for a definition of terms.

MODIS and Scheduler Processing Interactions (049). The interface specifications between the MODIS processing programs and the SCA process are being investigated.

> The MODIS process can be scheduled based on data availability or on the required generation of an output product. In either philosophy, tables of data availability must be kept by either the MODIS or the SCA process. The recommended contents of these tables and their driving forces are currently under investigation.

MODIS Data (013). All non-duplicate Level-0 data packets with an Application Process ID that designates MODIS data will be retained in the MODIS Level-1A product.

> Statistics containing duplicate packet, missing packet, and non-MODIS packet information will be included in the data product header and metadata. Quality assurance records, including but not limited to Moon looking, Sun looking, and other off-Earth looking indicators will also be included.

Level-1A Data Product Granules (014). MODIS Level-1A data will be stored as data product granules including a granule header. Each product granule will consist of a whole number of complete scan cubes.

The output data product will not contain partial scan cubes. The data product granule pre-allocation scheme utilizes a scan cube as a quantum of data. This scan cube quantum of data is the smallest unit that may be individually addressed to form a deliverable data set. Problems associated with duplicate, partially filled scan cubes which may occur at the beginning and ending of Level-1A granules will be resolved in the Level-1B processing.

MODIS-T scan cube is expected to be about 1.8 MegaBytes in size while a MODIS-N scan cube is expected to be about 1.4 MegaBytes. There will be approximately 600 MODIS-T scan cubes per orbit and approximately 5000 MODIS-N scan cubes per orbit (day/night distribution). This gives an approximate orbital data product size of 1.1 GigaBytes for MODIS-T and 5.7 GigaBytes for MODIS-N.

Level-1B Data Product Granules (029). During Level-1B processing, the data contained in each MODIS Level-1A data product granule will be subdivided into Level-1B data product granules.

This assumption implies that a Level-1B data product granule is a subset of one and only one Level-1A data product granule. This assumption specifically excludes the concept of a database storage granule which is a different concept than the product granule.

If more than one Level-1A granule is needed to produce a required Level-1B granule, this can be accomplished by executing the MODIS Level-1B process twice, once for each input data product granule. The MODIS processing design, utilizing a previously derived output product granule with missing data, will fill in the missing portions from the current processing output. This capability is similar to the reprocessing mode also implemented in the current design philosophy.

Granule Pre-Allocation (028). The operating system is assumed to provide the capability of preallocating output product storage for all MODIS processing levels before input data is processed.

The operating system will provide a facility under which a process can request both memory and disk space. This space will be preallocated to a process before the actual processing of data begins. If the space is not available, the MODIS process must be rescheduled at a later time when the resources are available. The size of the preallocated spaces is determined by the MODIS process at execution time and is derived from the size of the input data product.

Defining the sizes and locations of the output product for each execution of the MODIS process allows the MODIS product to be fully generated without any premature aborting of the process. This also simplifies the accounting and correlation of input versus output data products by the scheduler.

The pre-allocated areas are filled with invalid data indicators which are used by further processes in the chain for quality assurance assessment and reprocessing scenarios.

Level-0 Data Unpacking (016). MODIS data will not be unpacked (byte aligned) at Level-1A.

Leaving the data in a packed form minimizes the size of the data set in the absence of data compression. It also minimizes the time and complexity of Level-1A processing. Unpacking the data at Level-1A may increase the probability of error in the lowest level of permanently archived data.

Level-0 Data Packet Boundaries (015). A MODIS Level-0 instrument data packet will not contain data from more than one scan cube.

This assumption implies that the scan cube boundaries will fall on instrument packet boundaries. A packet of MODIS data will not be scattered across two or more scan cubes. There is no constraint on the relationship between frame boundaries and instrument packet boundaries.

A question has been directed to the MODIS-T instrument systems engineering section via the MODIS Characterization Support Team (MCST) containing a request to clarify the subdivision of a scan cube into frames and packets. A preliminary answer indicated that two CCSDS packets of data can contain one instrument frame of data and therefore gives a desirable boundary for the packets that coincides with the most desirable boundaries from a processing viewpoint. Note that the specifications for the MODIS-N and -T instruments specify "band interleaved by line" and "pixel interleaved by band" formats respectively for the two instruments. The pixel interleaved by band format is desirable from a science view point to minimize the effect upon a multi-band algorithm due to a missing data packet.

The above same question will directed toward the MODIS-N instrument system engineering section following contract award for this instrument.

Notification of Instrument Problems and Anomalies ( ). Generated messages, triggered by observations during the processing of MODIS data, will be transmitted to the MCST.

A list of status items, specifications of engineering limits, and data guality algorithms will be supplied by the MCST for incorporation into the MODIS processing chain. Any problems detected and anomalies derived from these checks will be formatted into messages that will be sent to the MCST. Requests that this information be send to other entities can be incorporated in revisions to the existing design.

Level-1A Instrument Status Comparison (018). MODIS Level-1A processing will not check instrument mode states or status contained in the Level-0 data against the Instrument Status Information maintained by the ICC.

The ICC command status log will not be available at the time of Level-1A processing. Therefore, it can not be performed without changing the current ICC plans.

If ICC commanding could be checked against telemetered commands and telemetered status, some problems could be detected in a more timely manner at an earlier stage in the processing chain.

Level-1B Instrument Status Comparison (045). The MODIS Level-1B processing will not check instrument states against the Instrument Status Information issued by the ICC.

The ICC log will not be available for examination until 48 hours after items have been posted to the log. This time constraint does not allow the MODIS process to compare telemetered data with commanded states. Problems or anomalies detected in the telemetered data stream will be posted to the MODIS data product log and made available to other functions as necessary.

Calibration (043). Calibration algorithms and parameter values will be provided by the MCST.

Both algorithms and parameters (coefficients) will be incorporated into the Level-1B software by the SDST. Any change of algorithms or parameters will force a Configuration Management revision update. A full software validation will be performed to detect overflow, underflow, error trapping, variable availability, etc.

Calibration Algorithms and Coefficients ( ). Neither calibration algorithms nor calibration coefficients will be contained within the MODIS Level-1A data product.

Calibration is performed in the Level-1B MODIS process using algorithms and coefficients that are fixed for a given revision of the code. There is currently no plan or requirement to incorporate a more flexible calibration proceedure. Note that this philosophy does not allow a smoothing of scene data across time frames greater than a Level-1B data product granule.

Level-1A Navigation (017). Earth locations of MODIS pixels will not be determined at Level-1A.

This function is contained in the Level-1B process.

Appending of Instrument Position and Attitude to the Level-1A Product (050). Satellite (Instrument) orbital location data will be appended to the MODIS Level-1A data product.

The instrument platform ancillary (platform ephemeris) data is included as part of the Level-1A data product. However, it could also be provided to the Level-1B process by an external entity rather than being embedded in the Level-1A product. This would lower the possibility of multiple versions of this spacecraft data that could then lead to a lack of concurrency.

As an additional point, this information is also expected to be used by other processes besides the MODIS processes. This information is also asynchronous in time to any instrument scan times and therefore must be interpolated to a process requested time. The position and attitude are contained in data packets with a spacecraft unique Application Process ID and may not be available or tracked by the DADS in coincidence with the MODIS (or other) data packets.

Platform Position and Attitude Knowledge (037). MODIS Level-1B processing will use the satellite, at instrument, position and attitude knowledge supplied by the EOS project and appended to the Level-1A data.

This assumption implies that the MODIS process will not be executed before the instrument position and attitude are known. If the instrument or spacecraft position and attitude are updated after the MODIS data product has been generated, a MODIS reprocessing may have to be initiated by an outside authority. The current MODIS design appends the instrument position and attitude to the Level-1A data product. This can lead to a lack of 'concurrency' (more than one version of a data set) with the attendant danger of not having the current, most accurate data. This instrument (spacecraft) location data set is supplied at the rate of ten times per second. This gives approximately 45 data samples for each MODIS-T scan cube.

Position and Attitude Knowledge for Quick_Look (052). MODIS Quick_Look processing will use the best available satellite position and attitude data.

For the Quick-Look mode, the best available position and attitude will be used with appropriate quality indicators. This may consist of data derived from orbital predicts or other similar methods.

Required Ancillary Data (042). All data required for MODIS Level-1B processing will be included in the MODIS Level-1A product.

(The data product is defined to include its associated metadata.) This assumption says that all data required to process the Level-1B product (including metadata) will be contained within the Level-1A data product. This means that no in-situ data is required, and that no auxiliary data sets are required (i.e. other instrument motions causing momentum effects, platform thermal deformation data not in the MODIS packets, previous MODIS data products, etc.). Each MODIS instrument is a stand-alone instrument. This means that other instrument data is not required to produce a MODIS data product up to and including the Level-2 data product. Note that calibration algorithms and coefficients are currently not included as part of the Level-1A data product. See also: Engineering Data, Appending of Instrument Position and Attitude.

Orbit and Attitude Correction (022). The process of updating instrument position and attitude information already appended to Level-1A data will be performed by a separate utility process.

The current design of the MODIS processor simply appends the spacecraft platform position and attitude data to the Level-1A data product. Thus a utility program can 'patch' the platform data with newer or more correct values without reprocessing the Level-1A instrument data. The data product must contain the version number of the platform position and attitude data in addition to the processing version number to provide a means of checking for inconsistencies. Products based upon a given Level-1A product that has been updated might need to be reprocessed and would require a backwards pointer to the data source with the appropriate database links.

Anchor Point Coordinate System (031). Earth coordinates will be represented in the geodetic latitude-longitude coordinate system on a standard ellipsoid.

Coordinate transformations from the EOS platform coordinate system to the ground based geodetic latitude-longitude coordinate system will be performed by the MODIS processor using standardized transformation routines. Latitude will be given in the geodetic coordinate system. Longitude is identical in either the geodetic or geocentric system. Spherical harmonics are not included in this coordinate system.

The satellite coordinate system is expected to be the World Geodetic System 84 (WGS84) model as used in the GPS positioning system. The Russian GLONASS GPS system utilizes the Ellipsoid Krasovskiy model which results in a .4 to .5 foot altitude difference and a 1 to 1.1 minute (sic.) latitude and longitude difference in actual aircraft flight testing.

Important: EOS may use the TDRSS onboard navigation system (TONS) in place of the GPS.system. Potential errors in the calculation of the anchor point locations are currently being re-examined given this change of navigation systems.

Anchor Point Selection (032). Within each scan cube, a set of anchor points will be selected for interpolating the ground locations of the pixels within the scan cube.

A non-linear set of approximately 150 anchor points per scan cube (3 along track, 51 across track) yields acceptable pixel positioning using a linear and cubic spline interpolation. See the report "An Analysis of MODIS Anchor Point Accuracies for Earth Location", MODIS Data Study Team, Revised: April 5, 1991 for details of the anchor point method accuracies. The ground locations of the selected pixels are determined solely from the satellite position, attitude, and instrument geometry without the use of ground (in-situ) control points.

Anchor Point Parameters (033). The following parameters will be provided in the Level-1B data set for each anchor point: earth location (geodetic latitude-longitude) of the pixel, satellite slant range, satellite azimuth and zenith angles, and solar azimuth and zenith angles (all with respect to the pixel).

The zenith angles are relative to the normal to the local geodetic surface at the pixel. Other needed parameters such as solar to spacecraft relative azimuth can easily be calculated from the appended parameters. The slant range facilitates the computation of any digital elevation model (DEM) corrections in later processes.

Anchor Point Error Statistics (034). No measure of earth pixel location accuracies will be included in the Level-1B data product.

These statistics can not be determined on a production basis. However, an indication of anchor point statistical angular variances can be derived externally in a non time critical environment by an auxiliary program. These angular accuracies are not unique to an individual data product. Pointing angles are to be derived from platform measurements initially and verified via off-line methods to be available after the MODIS data has been disseminated.

Level-1B Feature Identification (035) No Feature Identification or Ground Control Points will be used for Level-1B earth location.

No in-situ data, derived either from ground feature selection or a-priori positioning, will be required to geolocate the Level-1B data product.

Level-1B Elevation Correction (036). There will be no terrain elevation correction (beyond the reference ellipsoid) to earth location anchor points during Level-1B processing.

Any use of a Digital Elevation Model (DEM) will be performed in follow-on processing upon the determination of a DEM procedure and appropriate model.

Note that the use of a DEM model will necessitate the implementation of an iterative technique which will be non-reversable. If DEM is applied to Level-1B, follow-on processing will require the computaion of pixel locations from the satellite (instrument) position and attitude information, not ground anchor points. In addition, interpolation at pixel locations between anchor points that have had a DEM applied, will produce erronius results.

Atmospheric Correction (038). No atmospheric correction of any kind will be applied to the MODIS level-1B data.

The definition of MODIS Level-1B data is at-satellite radiances, uncorrected for atmospheric effects such as absorptive, scattering, and refraction.

Engineering Data (044). MODIS Level-1B processing will extract instrument engineering values from each Level-1A scan cube individually.

All of the instrument engineering values needed for calibration or other purposes, will be included in each scan cube of the Level-1A data product. No external data source will be required. All values required to perform a calibration of pixels within a scan cube will be contained within that same scan cube. Previous or future scan cube data will not be required to calibrate the current scan cube. If calibration requires a differing approach, the current design will require modification. Clarification and/or modification of this assumption is to be provided by the MCST.

Level-1A Land/Ocean Flags (024). Land/Ocean flags, Cloud flags, or other derived information will not be included in the Level-1A data product.

The scan data is in uncalibrated digital (raw) count form thereby precluding the use of any cloud detection algorithm at Level-1A.

Level-1B Land/Ocean Flags (039). Land/Ocean flags will not be included in the Level-1B data product.

The current Level-1B design contains no provision for data flags of any kind. Generating a land/ocean flag would require a Team Member agreed upon coast line database and can be added to the current processor design.

Level-1B Cloud Flags (051). Cloud flags will not be included in the Level-1B data product.

Cloud flag determination would require a definitive cloud detection algorithm or means for a multi-valued flag. Cloud algorithms are expected to be derived from MODIS-N data and possibly applied to MODIS-T data. This would require registration of the two MODIS products during the Level-1B product generation. Methods for implementing a co-registered cloud flag are being investigated.

Level-2 cloud Flags (009). A single cloud flag per pixel_band will be included in the Level-2 data product.

Every spatial pixel in the Level-2 data product will have a cloud flag attached. The algorithm for determining the cloudy condition will be provided by the MCST (verbal from J. Barker - 14 June 1991)

Level-1A Browse (026). There will be no Level-1A browse product.

Browsing a packed (not byte aligned) data set would be unnecessarily complicated. Browse data derived from raw instrument counts with no earth referencing would be of very limited use. Browse data requirements will be generated by the MODIS Science Team Members.

Level-1B Browse (041). The Level-1B process will not generate browse products.

Any required browse products will be generated by a separate browse process in order to take advantage of future technology advances without compromising the main data product processing. This allows technologies such as those currently in development for high definition television (HDTV), windowed graphical user interface (GUI), laser based video, or similar approaches to be used as they are developed without changing the basic Level-1B product generation function. This also allows for the concept of 'on the fly' or demand browse to be implemented.

Data Compression (027). No data compression will be performed within any of the MODIS processing levels.

Data compression, if implemented, is assumed to be performed in a process (hardware or software) that is external to any MODIS processing. This process is assumed to be a transparent, non delaying step, during the electronic transmission of data to/from storage. Software equivalents to hardware data compression techniques can be provided if necessary.

Metadata Appending (030). Each processing level updates and appends new metadata without deleting previous processing metadata information.

The metadata associated with an input product is updated to reflect further derived information. Previous metadata items are retained to allow backward tracking of information to the original source. This can be used for debugging and quality assurance determination. For example: The CDOS Reed-Solomon error statistics can be maintained with the mapped Level-3 product as an indication of the quality of that product. Metadata derived in the beginning of the processing chain will provide information which is useful for the generation of products later in that chain.

Level-1A Land/Ocean Product Separation (025). The Level-1A product will be supplied without separation into land/ocean or other categories.

Navigation is not performed in the Level-1A process. Therefore, earth referencing information is not available to allow a land/ocean flag to be generated.

Level-1B Land/Ocean Product Separation (040). The Level-1B product will be supplied without separation into land/ocean or other categories.

Level-1B MODIS data products are not categorized by spatial parameters when transferred to the archive although the headers and metadata contain statistics and indicators for this characterization. Data product splitting is a DADS function.

Level-1A Reversibility (020). Level-1A processing will be reversible to packets of Level-0 data.

The Level-1A data product, not the Level-0 data packets, will be permanently archived. Therefore, no non-redundant data will be deleted from the Level-0 packets in producing the Level-1A data product.

Level-1A Reversability (021). A separate software package will be provided to reverse Level-1A data to Level-0 data packets.

The separation of the forward and reversing processes allows one program to be modified or updated without disturbing the integrity of the other. This also decreases the size and complexity of these programs, but adds an additional program to the full validation and configuration management responsibility. Duplicate data packets and non-MODIS packets will not be regenerated.

The separate programs to perform Level-1A processing, to reverse Level-1A to Level-0, and to compare the original Level-0 packets with the reconstructed Level-0 packets, should optimally be written by independent parties to verify documentation of the data formats and eliminate any errors in the processing.

Level-1B Reversability ( ). Level-1B data will not be reversable to Level-1A.

There is no requirement that the Level-1A data product be regenerated from the Level-1B data product. This implies that the calibration algorithm applied to the raw instrument counts will be non-reversable. The final calibration algorithm is expected to be based upon a time based history of the instrument characterization to minimize discontinuities in the calibrated product.

Processing Log (023). A Processing Log, common to all MODIS processing programs, will be maintained consisting of a time ordered list of all MODIS processing events.

This Processing Log will receive messages in time order from all MODIS processing programs (Level-1A, Level-1B, Level-2, etc.). This allows an audit trail of MODIS problems and events that can be used as quality assurance inputs to other groups. The task of handling the MODIS Processing Log is performed by an external entity that is common to all MODIS processes.

Quick-Look Data Product (019). All Levels of Quick-Look data will be generated using the identical software as is used for the standard data product (assuming a time locality to the packet delivery in the case of the Level-1A product).

This design constraint assures that the revision level of any quick-look product matches that of the standard product and that only one piece of software is maintained. This satisfies the requirement of concurrency - only one definitive copy of a process. (See the discussion of the quick-look product in the Scenarios section of this document.)

The Level-1A processor is designed to accept data packets which are not in time order, provided that the packet sequence has reasonable time locality - the delivery of packet sequences is almost time ordered.

Level-1B Quick-Look (046). Level-1B Quick-Look data will be generated using the same version of software as is used for the standard Level-1B product.

(See the description under the Level-1A Quick_Look item for a discussion of concurrency.)

Quality Checks (010). Data quality checks will be included in the Level-1A and Level-1B MODIS processing programs.

The MSCT will provide an integrated set of quality checks from all sources, including team members. The MCST will also provide a list of error messages to be generated when the data fail to pass the quality checks.

GLOSSARY

Accuracy versus Knowledge - Pointing accuracy is determined directly from measurements contained within the telemetry. Pointing knowledge are accuracy measurements that have been corrected using non-measured means (derived platform precession or ground control point correction for example). Knowledge is obtained from characterization studies.

Application Process ID - A unique number in the packet header used to direct all packets with this ID to a given destination. This number is assigned by the CCSDS.

Browse - A sample of a data set that can be used to determine the characteristics of that data set. This sample may be compressed or subsampled spatially, temporaly, bit precission, or band wise.

Data Frame - Data from the detector array, clocked out simultaneously. This consists of the along track pixels within a scan swath for all bands (wave lengths or frequencies).

Granule - the smallest unit of data to be handled by a specified entity. The use of the term "granule" is used in the context of the discussion. For example: a data product granule is the smallest unit of a data product that is of use to a user of that granule. A computer storage granule can be a scan cube of data if that is the smallest addressable unit. Granule should always be prefaced with an adjective specifying the context in which the term is used.

Metadata - Auxiliary data, associated with a data set or product, that contains information describing the contents of that data set or product. The metadata can be used to derive indices in a database, or as selection criteria in place of the actual data set or product.

Packet - A physical block of data of fixed size used to transmit data with very good transmission integrity. The block contains redundant information that can be used to correct and/or detect errors in transmission.

Process - A computer program, or any of it's components (subroutines) or auxillary peers (external function) that performs a specified computational task.

Product - A data set consisting of one or more data files that have a logical relationship to each other.

Quick_Look - A data set that is generated in a time critical manner and may not be of final quality.

Scan Cube - All the instrument data that is derived or measured during one swath (half of a mirror rotation) of the instrument. The cube consists of three parts: science data, engineering data, and auxiliary data. The science data occurs as a spatial cube with an across track pixel count (1007 for MODIS-T, 1354+ for MODIS-N), an along track pixel count (30 lines for MODIS-T, 8+ for MODIS-N), and a number of bands in depth (32+2 for MODIS-T, 36 for MODIS-N). For each data frame, auxiliary data is appended, consisting of tilt and mirror encoder angular position and time tag. Engineering data constitutes the voltage, current, relay positions, thermistor data, etc.